Using multiple choice questions to assess chemical understanding

Mary Whitehouse, Judith Bennett, Lynda Dunlop, Kerry J. Knox

Earlier this year we carried out a synthesis of research related to the summative assessment of chemistry subject knowledge for the RSC (Bennett, Dunlop, Knox, & Whitehouse, 2017). From this study it became clear that much work has been undertaken into the development of effective assessment of chemical understanding using multiple choice questions (MCQ); it is some of that work that provides the background to this article.

As part of a suite of tools for summative assessment MCQ offer a number of inherent advantages, for example they can be marked reliably and quickly, making them cost and time efficient for large cohorts and they can be used to cover a broader range of content within a shorter test time than would be possible with open response questions alone (Black, 1998).

However making the most of the benefits of MCQs requires careful preparation, including the challenge of writing good questions where the distractors are appropriate and do not mislead students. Ideally MCQ should be pretested before they are used for high stakes testing. Concern has been raised by some critics is that it is possible that some students will gain marks by guessing the correct answer; various strategies have been reported to reduce the effect of guessing on the marks awarded (see, for example, Campbell, 2015).

An area of particular interest for teachers is the use of multiple choice questions for formative assessment. Combining good MCQs with mini whiteboards, *Plickers* < www.plickers.com >, *Socrative* < www.socrative.com >, or other ways of collecting responses makes it quick for a teacher to collect information about students' understanding, allowing the teaching to be adapted to meet the needs of the students (see for example, Allan, 2017).

Some of the constraints imposed when MCQ are used for high stakes testing do not apply when questions are used for formative assessment, and the answer architecture can be tailored to provide useful diagnostic information. For example, so-called 'ordered multiple choice questions' have been identified as being particularly useful for formative assessment. Hadenfeldt, Bernholt, Liu, Neumann, & Parchmann (2013) developed MCQ in which the possible responses represented different levels of understanding of ideas about the nature of matter. This development was based on a learning progression that reflected increasingly sophisticated understanding of ideas about the structure and composition of matter. The authors found that these questions discriminated as effectively as open response questions on the same topic. Development of such questions is shown to be an iterative process, in which the outcomes of using the questions not only informs the teaching of the current students, but also leads to further development of the original learning progression, as suggested by Wilson (2009).

A second development of the traditional MCQ answer architecture of particular value for formative assessment involves presenting the MCQ in a 'confidence grid' format as shown in Figure 1 (Whitehouse, 2014). We have found that students often do not want to make a clear choice between the possible answers to a multiple choice question. Converting a simple MCQ into a 'confidence grid' format enables the student to show their uncertainties, and the teacher to understand better where problems lie. The example question shown was developed from a question used in the *Assessing*

Students' Concept of a Substance project at Durham University (Johnson & Tymms, 2011). In questions of this type the distractors are incorrect ideas commonly held by students. In the original research Johnson and Tymms found that most students (61%) selected options **A** or **B**, with only 21% selecting the correct answer.

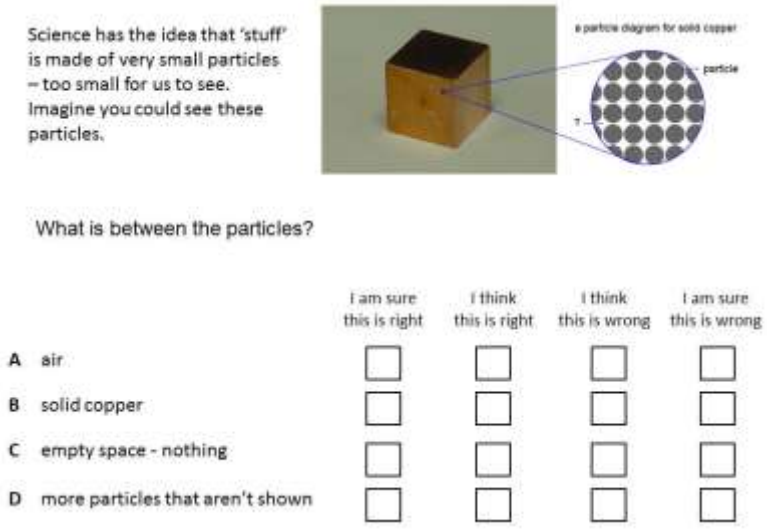

Figure 1 . A multiple-choice question presented in a 'confidence grid' format (adapted from Johnson & Tymms (2011)

Teachers have found the confidence grid a useful format for questions where many students have common alternative conceptions. Development of questions of this type will provide teachers with a better understanding of the ideas their students hold and as a consequence enable to the teacher to better tailor the lesson to the class. Research about students' ideas about chemistry provides plenty of inspiration for writing questions of this type (see, for example, Kind, 2004, Taber, 2002).

Other developments in multiple choice questions have been made possible by the increased use of on-screen assessment, including the use of two-tier questions and adaptive questioning where the route taken through the questions is determined by students' responses. Whatever the means of collecting the responses and whatever the question format, the quality of the answer options is key to their effective use to support learning.

Mary Whitehouse (@MaryUYSEG) is an Honorary Fellow in the University of York Science Education Group.

Judith Bennett is the Salters' Professor of Science Education at the University of York

Lynda Dunlop is a Lecturer in Science Education at the University of York

Kerry J. Knox is a Lecturer in Science Education at the University of York

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